A Study of the Growth Morphologies of Two Deep-Sea Manganese Meganodules[1]

MAURY MORGENSTEIN[2]

THE MORPHOLOGIES OF MANGANESE are numerous; commonly, they are classified as: micronodules, meganodules, crusts, botryoidals, and agglomerates. Within these classes are numerous shape categories. The purpose of this paper is to describe two, shape and surface-texture categories for manganese meganodules taken in a dredge (V16-SBT3) by Lamont-Doherty Geological Observatory near the Mid-Atlantic Ridge, at lat. 13°04′ S, long. 24°41′ W, in 4,700 meters water depth. Septarian concretionary features were observed on the bulk of the nodules, as were concentric manganese ring growths around rock centers, constituting the first known occurrence of this morphology in deep-sea sediments.

The nodules had seed centers of shark's tooth and palagonite. Most nodules showed an elliptical habit, but some were flattened and others were more spherical in shape. Most of the flattened nodules contained shark's tooth centers. The nodules that contained centers of altered basalt were elliptical or spherical. Three to four nodules appeared cemented together by manganite as agglomerates. In these "grape vine clusters," palagonite seed centers were more common than shark's tooth centers. Occasional flat manganese crusts were observed without any attached basaltic or bioclastic particles. These showed typical manganite layering of manganese oxides and iron complexes.

SEPTARIAN MANGANESE NODULES

Crack fillings were the most common surface feature observed on the nodules (fig. 1). Of about 500 specimens, smooth-surfaced nodules constituted less than 1 percent. No consistent geometric pattern was noted in the crack fillings. Although, grossly, they resembled tensile displacements commonly found in mud-crack configurations, the majority of the crack intersections were not orthogonal. A complete crack-filling history is available in the samples recovered. Freshly cracked nodules, deformed either by the dredging operation or natural circumstances such as impact during surface transport, showed cracks tapering off toward the center. The cracks generally did not extend to the seed.

Manganese growth in the cracks began at the outer edge and extended toward the center. At the same time, growth continued on the outer surface of the nodule. Commonly, the width of the crack-filling measured the same distance as the height of the filling above the unfractured surface. In these nodules, the septarian surface configuration apparently was maintained during the addition of manganite to the surface.

The "grapevine clusters" of manganese nodules commonly occur during the nodular fracturing and filling process as attested to by the presence of crack fillings at the intersections of two or more clustered nodules. The crack-filling process also acts as a cementing process when several nodules are in juxtaposition at the sediment-water interface, since additional manganese growth is generated by fracturing. Possibly, a collision between these nodules caused the cracks in the first place. In some instances, wedgelike nodular fragments were cemented by manganite to a fractured nodule at a crack intersection.

The rate of manganese growth within the fractures was not ascertained. However, Morgenstein and Felsher (see Pacific Science, this issue) have shown by hydration rim dating of palagonite seeds that nodules from this dredge have accretion rates ranging from 3.33 to 8.71 mm/10^6 years. They also showed that accretion

[1] Support for sampling came from the National Science Foundation, NSF-GA-19690, and from the Office of Naval Research, ONR (N00014-67-A-0108-0004). Hawaii Institute of Geophysics contribution number 316. Manuscript received August 3, 1970.

[2] University of Hawaii, Department of Geosciences, Honolulu, Hawaii 96822.

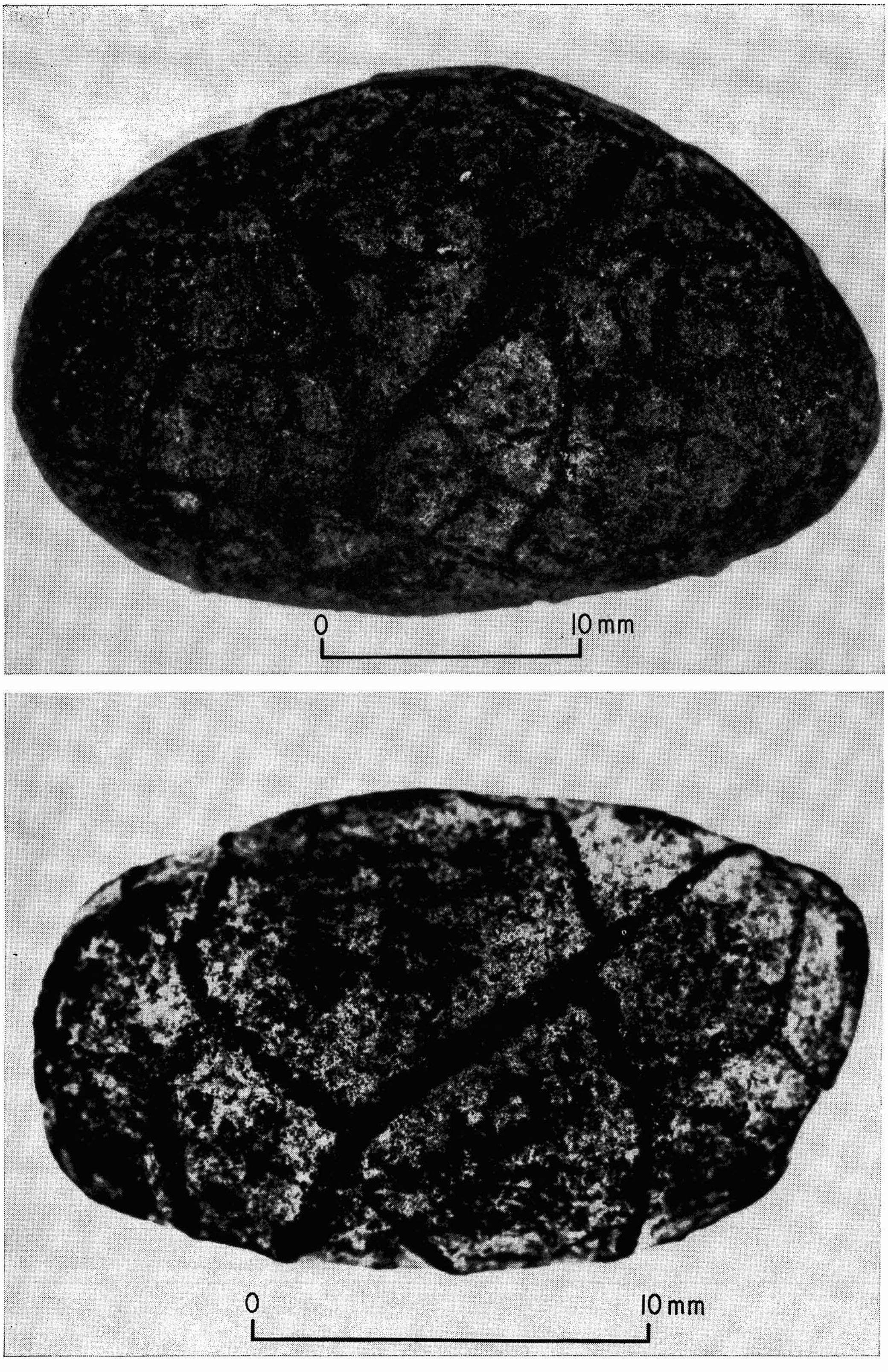

FIG. 1. Septarian manganese nodules showing crack fillings of manganite.

rates of these nodules decreased with increasing age. An assumption based on the latter observation suggests that the rate of nodular accretion is partially a function of the catalytic iron supply within the nodule seeds (Morgenstein and Felsher, Pacific Science, this issue). Generally, fracturing is able to make more catalytic agents available if these agents originate in the center of the nodules. Therefore, the rate of manganese accretion in the fractures may be explained as being more rapid than the unfractured "normal" nodular accretion. Obviously, iron oxides and other catalytic agents are not solely supplied to the nodules by palagonite hydration reactions within the nodules. Probably catalysts are supplied both from the seeds and from the surrounding sediment.

A further explanation for the greater accretion rate in the cracks than on the surface of the nodule involves a general calculation of the amount of surface area available for reaction. The actual rate of manganese deposited in the cracks may be consistent with the rate of the surface of the nodule; however, since there is an increase in the surface area by twofold at the cracks, more manganite can be formed there during any given unit period of time than on the surface of the nodule. Essentially, the cracks present two surfaces for manganite accretion whereas the remainder of the nodule presents only one surface.

No septarian ferromanganese nodules have been reported from lake sediments. Since lake nodules are more flattened (Dean, 1969) than are their oceanic counterparts, the chances for impact during surface transportation would seem quite limited. Therefore these nodules growing *in situ* do not form septarian features. The modes of formation of oceanic nodules and those from lacustrine environments would appear to differ. The following discussion of concentric manganese ring nodules suggests a corollary between the mode of formation of oceanic and lacustrine nodules.

CONCENTRIC MANGANESE RING NODULES

This writer first observed concentric manganese ring nodules taken from a freshwater lake in New York State by Dr. Walter Dean of Syracuse University. Dean observed that manganese ring growths formed around rock fragments located at the sediment-water interface (Dean, 1969; Harriss and Troup, 1969). Manganese nodules with a similar configuration from deep-sea sediments are shown in Fig. 2. Here, the rock centers were palagonite. They contained a fine coating (less than 1 mm) of manganese and had a heavy coating of an average of 12 mm in a ring configuration. Occasionally, manganite completely coated half of the seed centers while the other half was barren. The barren half was buried in the sediments, while the coated half marked the sediment-water interface.

It is entirely possible that the geometric manganese growth habit may be used to determine the location of the sediment-water interface in the geologic record. The appearance of nodules with ring configurations indicates a hiatus whose stratigraphic location can be defined within a few millimeters.

Careful study of such sedimentological configurations can accurately define changes of depositional rates as well as help to delineate changes in environmental conditions.

In summary, septarian manganese nodules are formed by a manganite crack-filling process acting on cracks formed by nodule impact during transport on the sediment surface. One major difference between the structure of deep-sea manganese nodules and that of lacustrine ferromanganese nodules is the difference in shape configuration. In the former case, the shape is controlled by bottom current transport; in the latter case, accretion occurs *in situ*. Although the septarian surface features point up the marked difference in nodular accretion in the two environments, the fact that concentric ring nodules occur in the marine environment as well as in the lacustrine environment, suggests that the modes of formation may be similar. The concentric ring growth habit of manganese around rock seed centers provides a new sedimentological tool for marine geologists. The manganese ring precisely defines the location of the sediment-water interface and defines the stratigraphic location of a period of nondeposition. The top and bottom sedimentary beds may also be distinguished by the presence of manganese coatings on the top surface of a seed and the

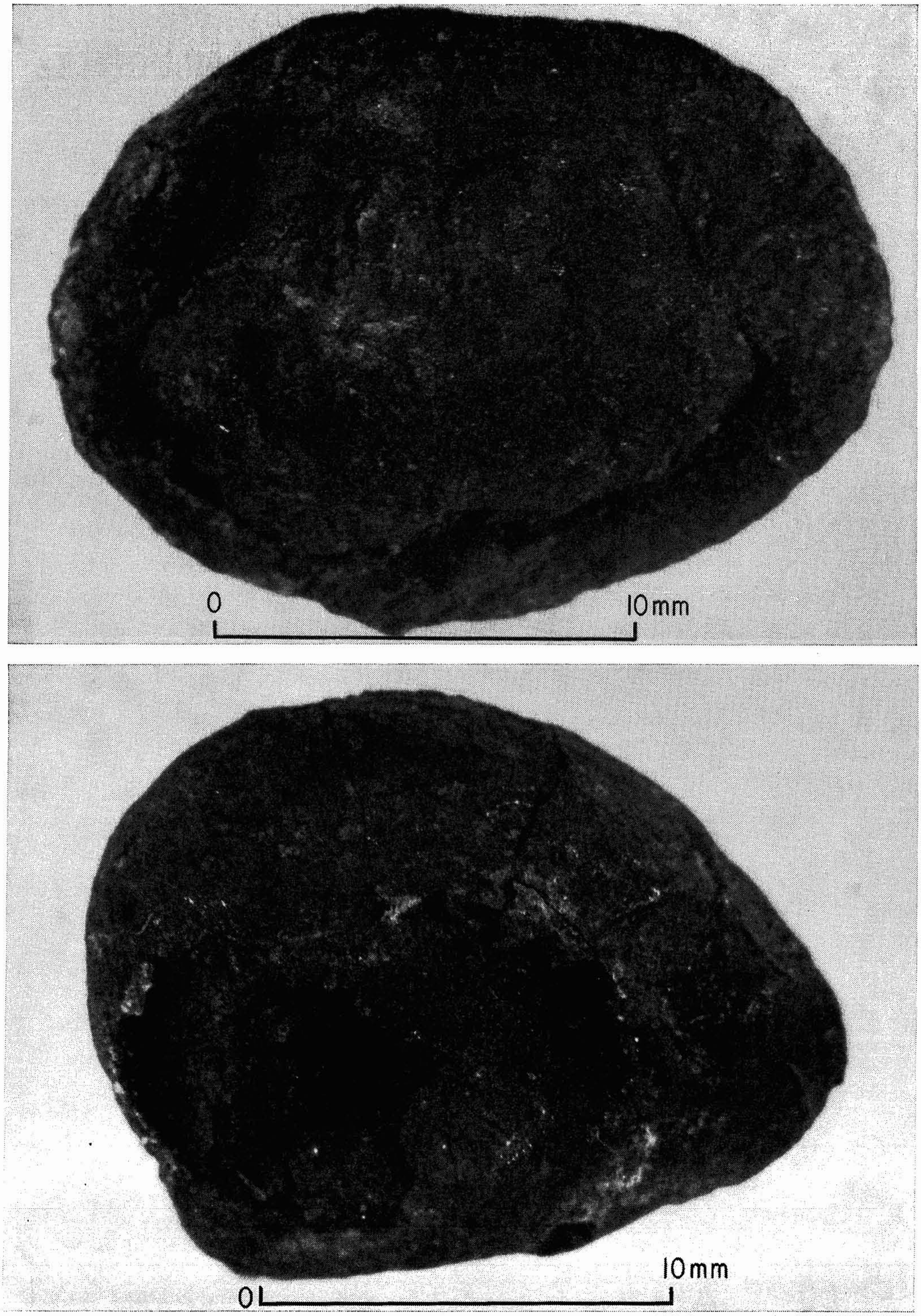

FIG. 2. Concentric manganese ring nodules with palagonite seed centers and manganite halos.

absence of manganese in the buried portion of the seed. Hopefully, new corollaries will appear between fresh- and salt-water manganese nodular accretions and may help to solve the long-existing problem of the origin of manganese nodules.

ACKNOWLEDGMENTS

Thanks are extended to Roy Capo of Lamont-Doherty Geological Observatory for providing the samples used in this study. James Andrews and Pow-foong Fan kindly read the manuscript.

LITERATURE CITED

DEAN, W. E., Jr. 1969. Freshwater iron-manganese "nodules" in Oneida Lake, New York. Geological Society of America Abstracts, p. 45.

HARRISS, R. C., and A. G. TROUP. 1969. Freshwater ferromanganese concretions: chemistry and internal structure. Science, vol. 166, pp. 604–606.

MORGENSTEIN, M., and M. FELSHER. 1971. The origin of manganese nodules: a combined theory with special reference to palagonitization. Pacific Science, vol. 25, no. 3, pp. 301–307. 5 figs.